# PERFORMANCE OF GRANULAR HERBICIDES FOR TRANSPLANTED RICE

by

W. L. Chang*

In recent years, several granular cambinations of grass-controlling herbicides with phenoxy herbicides have become available for weeding experiments. An experiment was set up in the first crop of 1969 at the Chiayi Agricultural Experiment Station in cooperation with the International Rice Research Institute (IRRI) to evaluate the weed control effects of these granular herbicides. The results of this experiment are briefey summarized in this paper.

## MATERIALS AND METHODS

The experiment was conducted in the first crop (Dry season) of 1969 at the wan-tien-li farm of the Chiayi Agricultural Experiment Station. In addition to 10 treatments suggested by IRRI, 5 reatments of 2,4-D and MCPA and hand weeding control were also included in the experiment (Table 1). The field experiment was laid out in a randomized block, split-plot design with four replications. Weed control treatments made the whole plots which was 3 × 4 m in size whereas rice varieties, an indica variety, Taichung native 1, and a japonica variety, Chiauung 242, comprised the subplots. Subplot size was 1.5 × 4 m and consisted of 6 rows from which the center 4 rows (1.0× 4 m or 4 $m^2$) was harvested for yield determination. The plant spacing was 25 by 20 cm. Fertilizers were applied by the conventional method at the rate of 80, 40, and 40 kg per ha for N, $P_2O_5$, and $K_2O$, respectively.

Mixed seeds of *Echinochloa crusgalli*, *Monochoria vaginalis*, and *Cyperus difformis* were broadcast on the plots immediately after transplanting at the rate of 2.0 kg per ha in order to insure a uniform and dense stand of weeds. Granular herbicides were applied directly to the shallow water (2-3 cm) 4 days after transplanting. For the application of MCPA and 2,4-D, water level of the plot was reduced to about 1 or 2 cm to expose the broadleaved weeds and sedges to the phenoxy herbicides. Levees were constructed between main plots.

Weed control and toxicity ratings were made at 15 and 30 days after application of chemicals as well as at panicle initiation stage based on 1 to 5 scale.

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Table 1. Treatments of herbicides

| Treatment | Formulation Concentration | Rate of application (kg/ha active ingredient) | Quantity of formulation (kg/ha or Liter/ha) | Time of application (Days after transplanting) |
|---|---|---|---|---|
| 1. TCE–styrene (G) | 3% | 0.75 | 25 | 4 |
| 2. TCE–styrene/2,4–D IPE(G) | 3%/2% | 0.75/0.5 | 25 | 4 |
| 3. Nitralin(G) + 2,4–D IPE (G) | 5%+10% | 1.50+0.8 | 30+8 | 4 |
| 4. Propachlor/2,4–D IOE (G) | 17.3%/3.3% | 2.50/0.5 | 15 | 4 |
| 5. Nitrofen (G) +2,4–D IPE (G) | 7%+10% | 2.00+0.8 | 25+8 | 4 |
| 6. 2,4–D IPE (G) | 10% | 0.80 | 8 | 4 |
| 7. EPTC/MCPA (G) | 4.38%/1.75% | 1.75/0.7 | 40 | 4 |
| 8. Trifluralin/MCPA (G) | 2.80%/3% | 0.70/0.8 | 25 | 4 |
| 9. MCPA–K salt (WSL) fb HW | 48% | 0.80 | 1.7 | 25&35 |
| 10. MCPA–K salt (WSL) | 40% | 0.80 | 2.0 | 35 |
| 11. MCPA–K/NA salt (WSL) | 48% | 0.80 | 1.7 | 35 |
| 12. 2,4–D Amine salt (WSL) | 72% | 0.80 | 1.1 | 35 |
| 13. 2,4–D Na salt (WP) | 85% | 0.80 | 0.94 | 45 |
| 14. MCPA Na salt (WP) | 85% | 0.80 | 0.94 | 45 |
| 15. Hand weeding contrnl | | | | 15,25,35&45 |
| 16. Untreated control | | | | |

IPE=Isopropyl ester. G=Granule. WP=Wetable powder. HW=Hand weeding. IOE=Iso–octyl ester. WSL=Water soluble liquid. fb =followed by.

Scale 1 indicates excellent weed control or no toxicity to rice whereas scale 5, no weed control or complete kill of rice plant. Grain yield and components of yield were also measured.

Unusually cold weather prevailed during the early stage of rice growth for almost 2 months before the weather returned to normal in the middle of April. The climatic data of the dry season crop are presented in Table 2.

## RESULTS AND DISCUSSION

### Weed Control and Rice Toxicity

Broadleaves were the predominant weeds of the experimental plots followed by sedges and grasses in the order of importance. The population densities in the untreated plots for broadleaves, sedges, and grasses were 480, 200, and 80 plants per $m^2$ respectively, when weed count was made one month after transplanting.

Table. 2. Climatic data of the first crop, 1969

| Period | Rainfall (mm) | Number of rainy days | Number of sunshine hours | Relative humidity (%) | Temperature (°C) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Maximum | Minimum | Mean |
| Feb. 11—20 | 0 | 0 | 4.7 | 65 | 26.6 | 15.6 | 21.1 |
| 21—28 | 1.9 | 2 | 2.1 | 78 | 22.2 | 13.4 | 17.8 |
| March 1—10 | 1.0 | 4 | 2.1 | 87 | 21.3 | 15.5 | 18.5 |
| 11—20 | 2.9 | 3 | 4.7 | 74 | 22.9 | 13.6 | 18.3 |
| 21—31 | 2.8 | 2 | 3.1 | 73 | 28.2 | 18.5 | 23.4 |
| April 1—10 | 2.2 | 2 | 4.1 | 67 | 26.8 | 15.7 | 21.2 |
| 11—20 | 4.9 | 1 | 3.3 | 75 | 28.8 | 21.0 | 24.9 |
| 21—30 | 0 | 0 | 3.7 | 72 | 30.7 | 22.6 | 26.7 |
| May. 1—10 | 0 | 0 | 3.7 | 67 | 31.5 | 23.7 | 27.6 |
| 11—20 | 0.3 | 1 | 4.7 | 62 | 33.2 | 25.3 | 29.3 |
| 21—30 | 14.5 | 6 | 2.2 | 68 | 30.1 | 22.9 | 26.6 |
| June 1—10 | 22.7 | 9 | 2.0 | 88 | 29.3 | 24.1 | 26.7 |
| 11—20 | 24.2 | 6 | 3.1 | 80 | 30.6 | 25.1 | 27.8 |

The most common broadleaves in the experimental plots were *Monochoria vaginalis*, *Marsilea quadrifolia*, *Eclipta prostrata*, and *Spirodela polyrhiza*. *Cyperus difformis* was the most important sedge whereas *Echinochloa crusgalli* and *Paspalum scrobiculatum*, the predominant grasses.

Weed control and rice toxicity ratings are presented in Table 3. Granular Nitrofen and 2, 4-D isoproppyl ester (IPE) applied simultaneously at the rate of 2.0 and 0.8 kg per ha respectively at 4 days after transplanting gave the best control of not only broad-leaf and sedge weeds but also grasses, indicating that the addition of 2, 4-D IPE greatly enhances the grass controlling ability of Nitrofen. Unfortunately, this combination also caused the heaviest phytotoxicity to rice plants. Taichung native 1, an indica variety, was found to be more sensitive to the toxicity of this chemical combination than the japonica variety, Chianung 242 at early stage of rice growth, but rice injuries were almost completely recovered at panicle initiation stage. Taichung native 1 appeared to recover faster than Chianung 242. Although weed control effect of Nitralin+2,4-D IPE ranked next to Nitrofen +2,4-D IPE, the former treatment appeared to be slightly less toxic to rice plants than the latter one.

It was of interest to note that single application of 2,4-D IPE provided good control of not only broadleaf and sedge weeds but also grasses with remarkably mild rice toxicity. TCE-styrene applied alone gave rather poor control of broadleaf and sedge weeds, but good control of these weeds were obtained when TCE-styrene was combined with 2,4-D IPE. TCE-styrene was not toxic to rice but TCE-styrene/2,4-D IPE caused slight rice

injury. The performance of Propachlor/2,4-D iso-octyl ester (IOE) was very similar to that of TCE-styrene/2,4-D IPE. *Marsilea quadrifolia* was not controlled by TCE-styrene, TCE-styrene/2,4-D IPE, Propachlor/2,4-D IOE and 2,4-D IPE.

Table 3. Weed control and rice toxicity ratings

| Treatment | Weed control | | | Rice toxicity | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 15 DAA | 30 DAA | PIS | 15 DAA | | 30 DAA | | PIS | |
| | | | | TN 1 | Ch 242 | TN 1 | Ch 242 | TN 1 | Ch 242 |
| 1 | 3.9 | 4.0 | 4.1 | 1.5 | 1.0 | 1.5 | 1.2 | 1.0 | 1.0 |
| 2 | 2.1 | 2.0 | 2.5 | 2.1 | 1.5 | 2.5 | 2.3 | 1.6 | 1.7 |
| 3 | 1.3 | 1.4 | 1.9 | 1.5 | 1.3 | 2.2 | 1.9 | 1.5 | 1.6 |
| 4 | 2.0 | 2.1 | 2.8 | 1.9 | 1.2 | 2.0 | 1.9 | 1.5 | 1.6 |
| 5 | 1.0 | 1.1 | 1.7 | 3.9 | 1.7 | 4.0 | 2.4 | 1.7 | 1.8 |
| 6 | 1.5 | 1.9 | 2.3 | 1.5 | 1.2 | 2.0 | 1.8 | 1.5 | 1.5 |
| 7 | 1.8 | 1.9 | 1.9 | 1.2 | 1.2 | 1.5 | 1.8 | 1.2 | 1.2 |
| 8 | 1.7 | 1.6 | 1.8 | 1.3 | 1.2 | 1.6 | 1.6 | 1.2 | 1.1 |
| 9 | 1.6 | 1.3 | 1.5 | 2.0 | 1.2 | 2.1 | 1.9 | 1.2 | 1.2 |
| 10 | 3.0 | — | 2.9 | 2.2 | 1.7 | — | — | 1.5 | 1.5 |
| 11 | 2.8 | — | 2.6 | 2.3 | 1.7 | — | — | 1.8 | 1.7 |
| 12 | 2.9 | — | 2.8 | 2.0 | 1.8 | — | — | 1.8 | 2.0 |
| 13 | 3.1 | — | 3.0 | 2.0 | 1.2 | — | — | 1.8 | 1.7 |
| 14 | 3.2 | — | 3.1 | 2.1 | 1.2 | — | — | 1.9 | 1.8 |
| 15 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 16 | 5.0 | 5.0 | 5.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

DAA=Days after application. TN 1=Taichung native 1.
PIS=Panicle initiation stage. Ch 242=Chianung 242.

EPTC/MCPA and Trifluralin/MCPA were found to be highly effective in controlling a very wide spectrum of weeds except *Marsilea quadrifolia*. Rice toxicity of these two chemical combinations was found to be very light. However, in another experiment conducted in the first crop of 1968, rice toxicity caused by EPTC/MCPA was found to be very severe (Chang, 1968) . The exact reason for this difference in rice toxicity caused by EPTC/MCPA is not presently clear. Granular Trifluralin/MCPA was found to provide better weed control and cause less rice injury in comparison with those of Trifluralin +MCPA formulated in water soluble liquid tested in the second crop of 1967 (Chang, 1968).

MCPA applied at the rate of 0.8 kg per ha of active ingredient at 25 days afer transplanting and followed by one hand weeding 10 days after the application resulted in the

good control of weeds and causing only slight phytotoxicity to rice plants. MCPA and 2,4-D controlled weeds poorly when they were applied at 35 and 45 days after transplanting. Weed control effects varied slightly among different salts of 2,4-D and MCPA, but amine salt of 2,4-D was apparently more toxic to rice especially to Japonica variety, Chianung 242 than sodium or potassium salts of 2,4-D or MCPA. Many sealed leaves were still visible even at heading stage in the plots of Chianung 242 treated with amine salt of 2,4-D. MCPA and 2,4-D gave good control or *Monochoria vaginalis* and *Cyperus difformis* but failed to control *Echinochloa crusgalli.*

*Paspalum scrobiculatum* which was only a minor weed at the early stage of rice growth became one of major weeds at the late stage of rice growth, showing that all chemicals tested in this experiment were unable to control this weed. *Spirodela polyrhiza,* a floating weed, were controlled only by Nirofen +2,4-D IPE and Nitralin+2,4-D IPE. The control of this weed is probably of minor importance as this weed was found to cause only slight decrease in rice yield even at a high population density of 300 plants per $m^2$ (Chang, 1969).

**Grain Yield and Components of Yield**

Although the growth of rice plants was affected by the cold weather in the early stage and also by the mild occurrence of rice blast disease at panicle initiation stage, the grain yields of hand weeding were typical for both Chianung 242 and Taichung native 1 obtainable at this station in the first (Dry season) crop. Hand weeding produced the highest yields for both rice varieties (Table 4). Application of 2,4-D amine salt and untreated control produced the lowest yield for Chianung 242 and Taichung native 1, respectively. The low yield of 2,4-D amine salt may be due largely to its severe phytotoxicity to rice plants whereas that of untreated control, to heavy infestation of weeds. Grain yields of MCPA and 2,4-D applied at 45 days after transplanting were among the lowest, but MCPA and 2,4-D applied either at 25 days after transplanting followed by one hand weeding or at 35 days after transplanting without hand weeding generally produced yields not significantly different from those of hand weeding in both varieties, showing that phenoxy herbicides applied at 25 and 35 days can be accepted as an effective weed control method in the first crop of rice. One hand weeding at 10 to 20 days after the application appears desirable as grasses are usually not controlled by these phenoxy herbicides. Amine salt of phenoxy herbicides appears unacceptable especially for Japonica rice varieties because of its severe phytotoxicity. The results of 2,4-D and MCPA were similar to those reported previously (Chang, 1965).

Table 4. Effect of herbicides on grain yield and components of yield

| Treat-ment | Taichung native 1 | | | | Chainung 242 | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain yield (kg/ha) | Panicles per hill | Grains per panicle | 100-grain weight (g) | Grain yield (kg/ha) | Panicles per hill | Grains per panicle | 100-grain weight (g) |
| 1 | 5,716 a-b* | 19.1 | 92.8 | 2.6 | 5,724 a* | 15.2 | 123.7 | 2.7 |
| 2 | 5,847 a-b | 21.6 | 117.6 | 2.6 | 5,030 b-e | 13.3 | 155.4 | 2.7 |
| 3 | 5,445 a-b | 18.3 | 100.4 | 2.5 | 5,322 a-d | 11.5 | 146.1 | 2.9 |
| 4 | 5,610 a-b | 17.9 | 107.9 | 2.5 | 5,376 a-d | 13.6 | 112.4 | 2.9 |
| 5 | 5,209 b-c | 17.3 | 123.3 | 2.4 | 4,876 b-e | 13.5 | 152.5 | 2.9 |
| 6 | 5,789 a-b | 17.8 | 122.2 | 2.5 | 5.382 a-d | 12.4 | 134.9 | 2.9 |
| 7 | 6,068 a | 19.7 | 102.7 | 2.4 | 5,568 a-c | 14.6 | 136.4 | 2.9 |
| 8 | 6,058 a | 18.8 | 119.0 | 2.3 | 5,987 a-b | 15.1 | 156.8 | 2.7 |
| 9 | 6,078 a | 19.4 | 107.9 | 2.4 | 5,557 a-c | 13.4 | 137.1 | 2.8 |
| 10 | 5,745 a-b | 18.4 | 124.2 | 2.4 | 5,401 a-d | 14.5 | 148.1 | 2.8 |
| 11 | 5,649 a-b | 17.8 | 126.8 | 2.4 | 5,701 a-b | 13.0 | 180.0 | 3.0 |
| 12 | 5,176 b-c | 17.9 | 121.4 | 2.4 | 2,913 f | 13.6 | 116.3 | 2.8 |
| 13 | 5,024 b-c | 20.7 | 93,1 | 2.3 | 4,559 d-e | 14.6 | 113.3 | 2.9 |
| 14 | 5,068 b-c | 17.8 | 107.4 | 2.5 | 4,676 c-e | 13.4 | 132.6 | 2.8 |
| 15 | 6,162 a | 21.1 | 110.3 | 2.4 | 6,026 a | 17.5 | 154.2 | 2.6 |
| 16 | 4,572 c | 16.1 | 97.6 | 2.5 | 4,361 e | 11.8 | 127.2 | 2.8 |

*Letters with a dash beteen are inclusive for the range, grain yields with letters in common are not significantly different from each other at the 5% level.

Granular TCE-styrene applied alone produced yields comparable to those of hand weeding in both varieties even though its weed control effect was the poorest. It was found that although *Monochoria vaginalis* and *Cyperus difformis* were not killed by TCE-styrene, their growth was somewhat delayed in comparison with that of untreated check and this inhibition effect on weed growth at the early growth stage of rice may have contributed to the reduction of weed competition with rice plants.

Granular 2,4-D IPE applied alone at 4 days after transplanting was found to provide satisfactory weed control and to produce reasonably high yields with remarkably light phytotoxicity in both rice varieties. However, when 2,4-D IPE and 2,4-D IOE were combined with TCE-styrene, Nitralin, Propachlor and Nitrofen, grain yields were generally decreased because these combinations were more toxic to rice, although their weed control effects were greatly improved. Further investigation with granular 2,4-D appears necessary.

The grain yields of EPTC/MCPA and Trifluralin/MCPA were only next to those of hand weeding in both varieties. The high grain yields of these two treatments may be largely attributable to their good weed control effects as well as their low phytotocicity

to rice. The performance of these two chemicals in this experiment clearly indicated that EPTC/MCPA and Trifluralin/MCPA may be acceptable as commercial herbicides for transplanted rice in Taiwan. However, as EPTC/MCPA was found to be highly toxic to rice in another experiment (Chang, 1968), it seems reasonable to suggest that more investigations should be made on these two promising chemicals before they are formally recommended to farmers.

The application of herbicides generally reduced the number of panicles per hill and the number of grains per panicle but the 100-grain weight was not greatly affected. The yield components of japonica variety, Chianung 242 were found to be more susceptible to chemical injury than indica variety, Taichung native 1, resulting in greater decrease in grain yields Although Taichung native 1 was found to be more susceptible to the chemical injury at the early stage of growth, its recovery was apparently faster than that of Chianung 242, due presumably to its stronger tillering ability. The decrease in grain yields was associated with the decreases in the number of panicles per hill and/or the number of grains per panicle.

## SUMMARY

The results of a herbicide experiment for transplanted rice conducted at the Chiayi Agricultural Experiment Station in the first crop of 1969 are briefly summarized.

Nitrofen (G) +2,4-D IPE (G) gave the best control of weed followed by Nitralin (G ) +2,4-D IPE (G) . MCPA+HW, EPTC/MCPA (G) , and Trifluralin/MCPA (G) also provided good control of weeds. TCE-styrene and late application of 2,4-D or MCPA resulted in a poor control of weeds. A satisfactory control of weeds was also obtained by 2,4-D IPE (G) , TCE-styrene/2,4-D IPE (G) , and Propachlor/2,4-D IOE (G).

Rice toxicity was generally light except the treatments of Nitrofen (G) + 2,4-D IPE (G) and 2,4-D amine salt, and mot of rice injuries were recovered before panicle initiation stage. Taichung native 1, an ndica variety, was more sensitive to phytotoxicity in the early stage of rice growth than Chanung 242, a japonica one, but the former variety recovered more quickly and suffered less yield reduction than the latter one.

Hand weeding produced the highest grain yields followed by MCPA + HW and EPTC/MCPA (G) in Taichung native 1 and by Trifluralin/MCPA (G) and TCE-styrene in Chianung 242. The lowest yields were produced by untreated control in Taichung native 1 and by 2,4-D amine salt in Chianung 242. The decrease in grain yield was associated with the reduction of the number of panicles per hill and/or the number of grains per panicle.

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# 水田粒狀除草劑之治草效果

張 萬 來

嘉義農業試驗分所與國際稻米研究所合作於民國58年第1期作舉辦水田粒狀除草劑藥效試驗，茲將其結果摘要如下：

Nitroten 粒劑 + 2,4-D IPE 粒劑之治草效果最佳 Nitralin 粒劑 + 2.4-D IPE 粒劑次之。MCPA加一次人工除草， EPTC/MCPA 粒劑，與 Trifluralin/MCPA 粒劑之治草效果亦佳，惟 TCE-styrene 與後期施用 2,4-D 及 MCPA，其治草效果則較差。 2,4- D IPE 粒劑， TCE-styrene/2,4-D IPE 粒劑，與 Propachlor/2,4-D IOE 粒劑亦具相當程度之治草效果。

水稻藥害除 Nitrofen 粒劑 +2,4-D IPE 粒劑與 2,4-D 胺鹽處理較爲嚴重外 ，其餘均甚輕微，且多能在幼穗形成期以前復原，籼型稻臺中在來1號在生育初期較粳型稻嘉農242號易受藥害，惟前者復原情形較後者良好，故前者因藥害而減產之程度較後者輕微。

稻谷產量兩品種均以人工除草區者爲最高，第二與第三高產處理在臺中在來1號爲 MCPA + 人工除草與 EPTC/MCPA, ，而在嘉農242號則爲 Tritluralin/MCPA 與 TCE-styrene 。產量最低之處理在臺中在來1號爲不除草區而在嘉農242號則爲 2,4-D 胺鹽處理。每株穗數與（或）每穗粒數之減少似爲稻谷產量低減之主要原因。